Top-down archaeology: High resolution satellite images of Rapa Nui on Google Earth™ *

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A Conservation Ethic

The archaeological record is, by its very nature, nonrenewable. Each aspect of the record comprises unique information, the sum of which provides the only testament for vast amounts of human history in space and time. The recognition of the nonrenewable character of the archaeological record has led to the compelling rationale for a "conservation ethic" (Lipe 1974).

A conservation ethic demands that we minimize damage to the archaeological record whenever possible for two different, but complementary reasons (Dunnell and Dancey 1978; Dunnell 1984; Moratto and Kelly 1977). First, we must endeavor to preserve cultural heritage for its own sake, since it has intrinsic and diverse values to living populations. Such heritage has cultural, symbolic, political, and aesthetic values, among others. Second, preservation of archaeological phenomena is a scientific imperative, since such phenomena comprise the only empirical record of our past that is subject to scientific explanation. Thus as archaeologists we must seek to preserve the record even in the course of our continuing research. As students of archaeology learn from the outset, archaeological research is often destructive – we sometimes destroy what we study and seek to preserve – like the metaphor of tearing the pages from a book as we read it. Despite this paradox, archaeologists must be fervent advocates for preservation.

In continuing research of the archaeological record the conservation ethic should guide our choices of data generation techniques. While the "standard" techniques of excavation and survey are just two sets of strategies that potentially provide us information, we need to document the archaeological record in ways that best address our research questions. Combining research interests and a conservation ethic, our field strategies comprise the *cheapest* (i.e., most efficient) means for generating observations of archaeological phenomena, which in turn employs means that are usually the *least damaging* to the record. Choosing field research techniques should include as many kinds of observations as possible since the record has potentially many artificial characteristics expressed in visible light, electromagnetic spectra, as well as variations in chemical and physical form resulting from human behavior and expressed at scales ranging from the ion to the landscape. We should acquire and overlay as many classes of information as possible, with minimal impacts to the archaeological record, employing iterative sampling designs generating data until reaching redundancy in specified classes of information at levels of precision required to resolve problems of interest. For scientific archaeology, Dunnell (1982:7) has described the methodological dimensions of empirical sufficiency (i.e., Are units of meaning measurable in the empirical realm?) and their relation to tolerance limits (How close is close enough in our measurements?); see also Hunt et al. 2001. In concert with dynamic sufficiency (i.e., completeness of theory), our efforts should focus on decreasing the gaps between explanatory accounts (i.e., models and hypotheses) and our particular case (Dunnell 1982; Hunt et al. 2001).

"Top-Down" Archaeology

The organization of the dizzying array of possible archaeological observations into a research management strategy is accomplished by taking a "top-down" approach (Figure 1). In this way, we begin our work with inexpensive and high-

Technique	*Scale*	*Invasiveness*
Satellite Image	*Large*	*Minimum*
Aerial Photography		
Kite Photography		
Pedestrian Survey		
Geophysical Survey		
Surface Mapping		
Auger holes		
Excavation	*Small*	*Maximum*

Figure 1. A top-down field research model for archaeology emphasizing the conservation ethic.

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resolution satellite imagery to determine the distribution of alterations from human actions across a landscape. We then could use publicly-available infrared, sub-meter resolution low-level aerial photographs available for many years and different seasons to map topography, soil and vegetation differences or to examine areas in their historic context. Based on hypotheses about the relationship of the composition of the archaeological record with the landscape generated from the satellite and aerial images, we can then zoom in on areas with low-level aerial photographs available from kite- or balloon-based platforms to document structures and objects at the scale of portable artifacts. For example, we could ask how patterns visible in small-scale imagery might be areas that are compositionally distinct as a consequence of cultural debris deposited on the surface.

Today, using guidance from satellite and aerial images, we might expand our sensory picture of the target area through intensive ground-based surveys and surface mapping to generate data for the spatial distribution of sub-meter scale artifacts and the details of features. This work might be followed with geophysical studies of images in predetermined areas in order to map compositional information about subsurface and near-surface deposits. Targeted areas could also be characterized using geophysical methods such as resistivity and ground penetrating radar or any of the other near-surface remote sensing techniques that are currently available. Each of these techniques provides a means of resolving *structure* (i.e., patterns of variability) in the archaeological record. Subsequent work might layer information obtained by inexpensive small-hole excavations (i.e., coring) that can be used to acquire micro-artifact samples as well as smaller sediment and ion-sized artifact information (e.g., "artificial" chemical concentrations such as phosphorous). These classes of data at combined scales form a robust understanding of the archaeological record in the context of the landscape upon which it is distributed.

Rapa Nui

On Rapa Nui, some of the scales of inquiry have seen more use than others. Landscape approaches have tended to dominate research practices (e.g., McCoy 1976; Cristino et al. 1981; Stevenson 1984; Vargas 1998; Vargas et al. 1998). Examining the record at the scale of the landscape has provided insight into variability in settlement and subsistence patterns (e.g., Vargas et al. 2006). Part of the emphasis on landscapes is a consequence of the practical and conceptual difficulty of working at smaller scales, particularly relevant given the problematic notion of "site" (Dunnell 1992). It is clear to most researchers that the archaeological landscape of Rapa Nui exemplifies the impracticality of the "site" as a unit of observation, recording, and analysis. At least in some domains, the "site" has been regarded as a discrete archaeological unit with ethnographic connotations of "community" (Willey and Philllips 1958), as has been common in Polynesian archaeology. On Rapa Nui, however, with a nearly continuous distribution of artifacts along scales ranging from small objects to monumental architecture spread over the surface of the island, any identification of "site" from any scale of observation remains decidedly arbitrary.

Unfortunately, even though research has tended to emphasize landscape scale patterning and distributions, the units of observation have focused on intuitive ethnographic or "*emic*" classes (Commendador 2005). These classes (e.g., *umu, hare moa, hare paenga*), while useful shorthand for communicating general observations, tend to compress variability in typological units, idealize forms, and render meaningful analysis of these entities difficult, particularly outside of an ethnographic context. This problem can be avoided through an *analytic* approach to the functional and stylistic structure of the archaeological record of Rapa Nui. Such an analytic approach examines patterning at multiple scales – artifacts, their aggregations, and multiple aggregations – without the imposition of the "site," variously conceived. "Non-site" analytic approaches have been successfully demonstrated in other contexts (e.g., Dunnell 1983; Dunnell and Campbell 1977; Ebert 1992), and are certainly applicable to our examinations of the archaeological phenomena of Rapa Nui.

Satellite Images

In top-down archaeological research design, satellite images provide an initial means for generating information on the archaeological record over the largest areas. Over the past several decades, satellite imagery has become a powerful and efficient means for documenting the structure of the earth's surface over large areas. The potential of satellite images in archaeological research, however, is only beginning to be recognized. Part of the slow rate of adoption of satellite-based research in archaeology has been the relatively high cost, the technological knowledge required, and the comparatively low-resolution of images available from early satellites. Thus, the earliest uses of satellite images were limited mostly to remote sensing specialists and the study of landscapes or large archaeological features (e.g., Allan and Richards 1983; Custer 1986; Ebert 1980; Findlow and Confield 1980; Schalk and Lyons 1976).

The past several years, however, have seen an explosion of new sources of satellite images with increasing resolution integrated into user-friendly tools. These new sources include declassified military imagery and the establishment of commercial firms that have launched their own satellites. A new generation of satellites such as Corona, SPIN-2, Orbview-3/4, SPOT, EROS, and Ikonos provide high resolution images[1] that are well below 10 m and available at low cost. Since these images are capable of resolving features of archaeological interest (e.g., structures, deposits), their use has spawned a wide variety of applications in archaeologi-

[1] In general, "high resolution imagery" is defined as a representation of the Earth's surface of less than 10 m^2 (Forte 2001:132).

cal research (e.g., Failmezger 2001; Fowler, 1996, 2002; Kennedy 1998, Kouchoukos 2001; Lipo and Hunt 2005; Mumford and Parcak 2002; Philip et al. 2002).

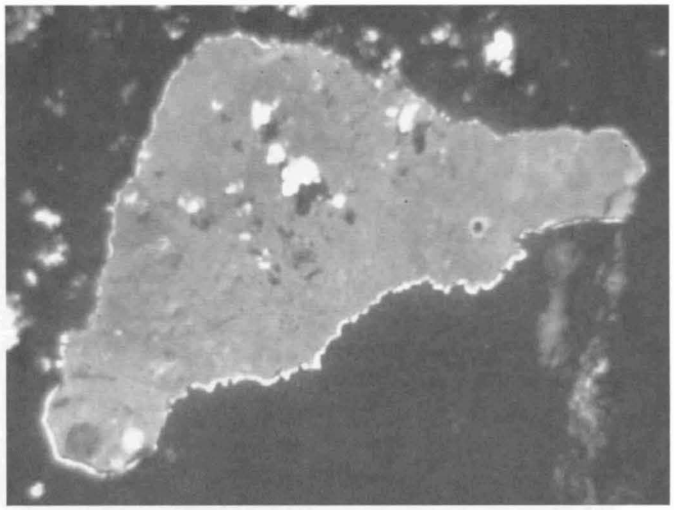
Significantly, the resolution of recent satellite images has proven to be sufficient to resolve linear prehistoric features such as roads (e.g., Ur 2003; Sever and Wagner 1991) and even footpaths (McKee et al. 1994; Sheets and Sever 1991; Sheets 2003). As we showed recently (Lipo and Hunt 2005), it is possible to detect features related to Rapa Nui statue (*moai*) roads provided one can acquire images that resolve features ca. 2 to 5 m across and if views of *moai* road related-features are not obstructed by vegetation or other kinds of ground cover. When these conditions are met, it is possible to construct a map of the prehistoric roads and use satellite images as a primary means to study at least some portion of the paths across which the *moai* were moved (Lipo and Hunt 2005). As the readers of this journal will appreciate, the sparse vegetation of Rapa Nui provides an ideal location for an array of remote sensing applications.

In our initial work using satellite data, we acquired images from DigitalGlobe's QuickBird satellite. This commercial satellite was launched in 2001, orbits the earth every 93.5 minutes and revisits its path every 1 to 3.5 days depending on latitude. Remarkably, the QuickBird satellite is capable of generating panchromatic images with resolutions of 61 to 72 cm and multi-spectral images with resolutions of 244 to 288 cm. Differences in resolutions depend on the degree to which the satellite is off from the nadir when the image is taken. Data in the DigitalGlobe images are geo-processed so that points and features can be located with an accuracy of 23 m at 90% circular error.

The resolution of the QuickBird satellite provides images that are comparable with aerial photographs typically taken at high elevations. Studies have shown that QuickBird imagery is of sufficient resolution to provide a base for mapping between 1 in = 200 ft and 1 in = 400 ft scale (Nale 2002). One of the advantages of QuickBird is its ability to acquire data at near nadir and that the corresponding digital imagery may be considered true orthophotos. An additional advantage that QuickBird has over aerial photographs is that images are available in color, panchroma, and 4-band multi-spectra ranging from blue to near-infrared (400 nm – 900 nm). This multi-spectral information, though at a lower resolution (ca. 2.4 m), is of sufficient quality to provide for a broad range of vegetation and environmental information. Natural color imagery can provide crop, forest, and wetland information. Remarkably, all of these datasets are available for areas across most of the Earth for about US$30 per square kilometer.

Google Earth Imagery for Rapa Nui

One recently available means of displaying data in a spatially integrative fashion is Google Earth[2]. Google Earth mapping service is a free application for browsing and viewing maps, imagery and data from around the world. Utilizing an intuitive graphical interface, images and data are streamed over the Internet to the application as one zooms and "flies" across the planet. The application is impressive and sports imagery across the entire Earth. One particularly useful feature of Google Earth is that for many areas high-resolution color satellite imagery is available[3]. In November 2006, Google added imagery for Rapa Nui with one-meter resolution (Figure 2). Although a small area of the northern edge of the island is missing and some small portions of the island are covered by clouds, this imagery represents the most complete and highest-resolution coverage for the island that is currently publicly (and *freely*) available. The images provide a remarkable source of information on the environment, landscape, land-use, and the archaeological record, clearly displaying architectural features, *ahu*, paths of *moai* roads and the position of *moai*, *manavai* (agricultural enclosures), and even concentrations of agricultural rock mulch (e.g., see Bork et al. 2004; Wozniak 1999), among many other features. Figures 3 to 9 provide examples of features visible on Rapa Nui in images from Google Earth. We also note that high-resolution images are available for many Pacific Islands (see Figure 10, a view of the Maeva area of Huahine Island, Society Islands, including stone-constructed fish traps).



.Figure 2. Satellite image of Rapa Nui (Image 2007 NASA).

In our continuing field research addressing multiple aspects of Rapa Nui prehistory we have integrated commercially available satellite images, free images from Google Earth, kite- and blimp-based low elevation aerial photography with pedestrian surveys, mapping, geophysical techniques, and small-scale excavations (e.g., Ayala et al. 2005; Lipo and Hunt 2005; Lipo et al. 2005). This top-down approach is inspired by the conservation ethic that we outline in this paper. Figures 11 and 12 illustrate the correspondence of Google Earth imagery and the higher resolution counterparts of kite/blimp photography of the same areas of

[2] http://earth.google.com/
[3] This imagery is regularly added to and updated by Google.

Figure 3. Satellite image of Rano Raraku statue *(moai)* quarry (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 4. Satellite image of Puna Pau Crater red-scoria top-knot *(pukao)* quarry; the *pukao* are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 5. Satellite image of Akahanga, southern coast; the coastal *ahu,* modern roads, stone mulch areas, and other features are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 6. Satellite image of an interior area of Akahanga where multiple *manavai* (agricultural enclosure) clusters are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 7. Satellite image of an interior area of Akahanga where *moai* road features, historic *pirca (*walls), and modern agricultural fields are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

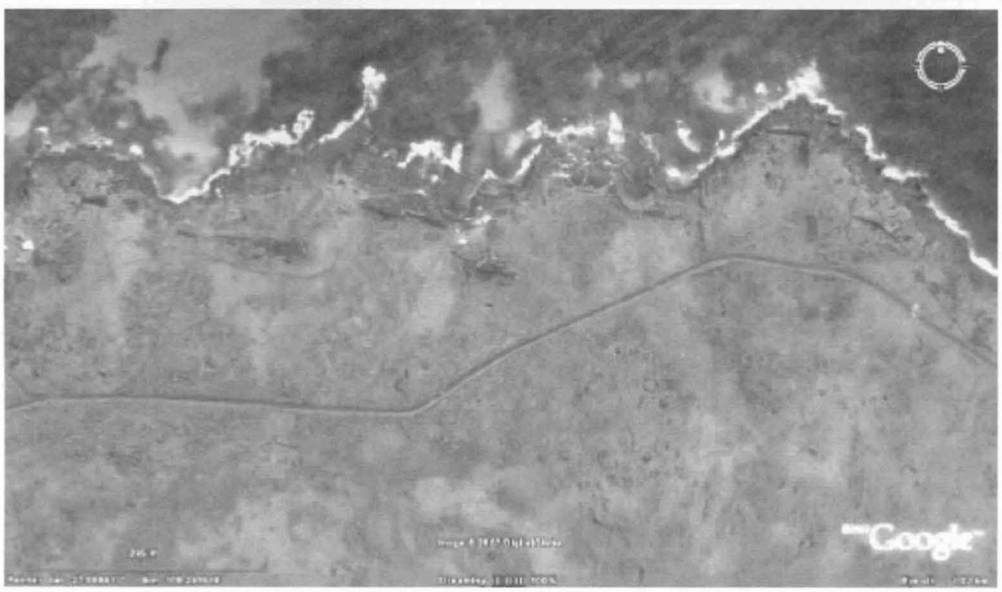
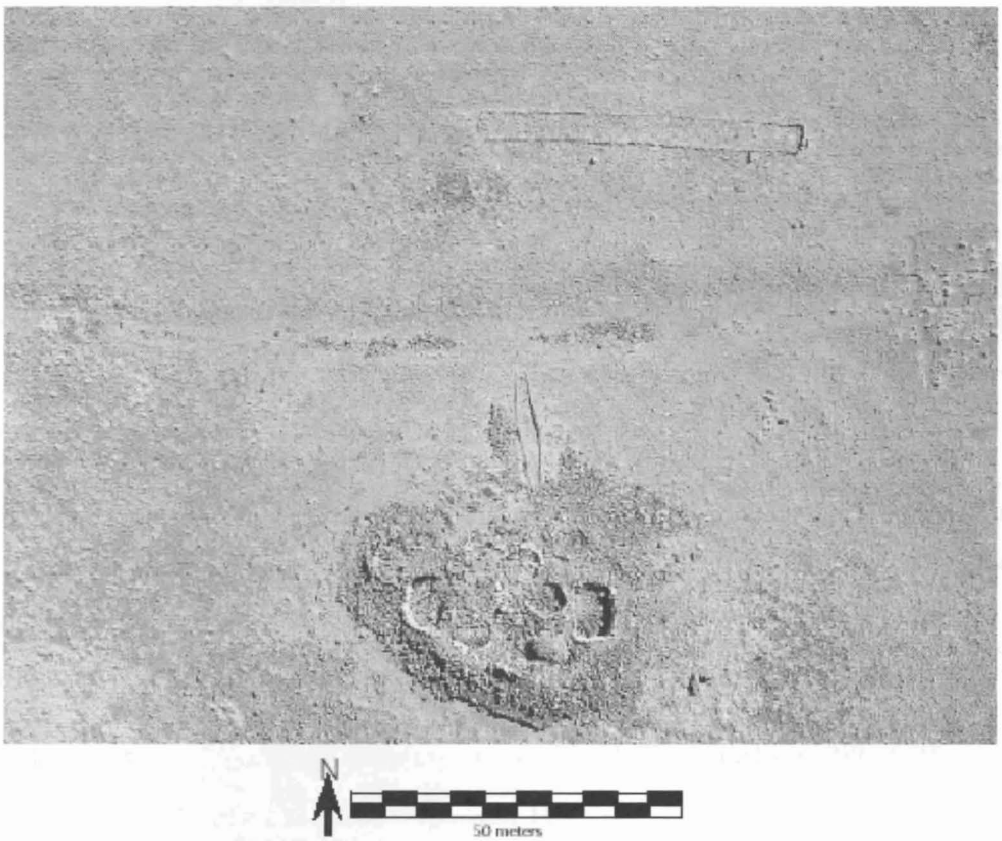


Figure 8. Satellite image of Hanga Ho'onu, northeast coast; several large *ahu* structures are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 9. Satellite image of an interior area near Maunga Te Kahu Rere, south coast, where land-use changes in developing *parcelas* for agriculture are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 10. Satellite image of Maeva area of Huahine Island, Society Islands, French Polynesia; the *marae* complex and traditional fish traps are visible (from Google Earth Mapping Service, http://earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).

Figure 11. Satellite image of an interior area of Oroi, south coast; the *moai* road, *hare paenga, manavai,* and other features are visible, but note the greater detail in the kite photograph show in Figure 12 (from Google Earth Mapping Service, http:// earth.google.com, Image © 2007 DigitalGlobe, Image © 2007 NASA).



12. A kite-based aerial photograph of archaeological features in the interior area of Oroi, south coast; the higher resolution clearly shows the *moai* road, *hare paenga, manavai,* and other features, but in greater detail than in the satellite image (Figure 11). Low elevation photography from a kite- or blimp-platform provides details useful in documenting the archaeological record.

the south coast (near Ahu Oroi) of Rapa Nui. For complex, fragile, and sensitive architectural features such as *ahu*, the integration of remote imagery from satellites and kites provides unmatched data in producing detailed maps. Such maps could be produced with little, if any, direct contact with the structure (e.g., walking over it). As preservation concerns increase with continuing impacts, particularly in the remarkable archaeological record of Rapa Nui, these non-invasive mapping techniques will likely prove essential.

We suggest that field data can be mapped and provided in its spatial context using Google Earth and displaying data, such as for *moai*, *ahu*, *moai* roads, and other archaeological features for sharing using Internet venues, as we have developed with the Museo Antropológico P. Sebastián Englert (e.g., Torres Hochstetter et al. in press). Public access and sharing of data – for the Rapanui and research communities in particular – have become particularly urgent with rapid land-use changes on the island.

The recently and freely available high-resolution satellite images from Google Earth should prove useful to researchers working on Rapa Nui. Integration of these sources, no longer just economical, but now *free*, facilitates a top-down research strategy and a conservation ethic. It should also prove to be a vital tool in integrating and sharing archaeological data for purposes of research and preservation (see Kintigh 2006).

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